RESEARCH TRIANGLE INSTITUTE

Operations Research and Economics Division

PROTECTION ANALYSIS AND CONSTRUCTION EVALUATION SYSTEM

FINAL REPORT R-OU-205

Prepared for

Office of Civil Defense
Technical Services Directorate, Architectural
and Engineering Services Division
Department of Army - OSA

under

Contract No. OCD-PS-65-47

RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

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by

F. A. Bryan, Jr., E. L. Hill, B. W. Howard,
T. Johnson, R. O. Lyday, P. S. McMullan, and
M. D. Wright

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Approved by:

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15 January 1966

THE RESEARCH TRIANGLE INSTITUTE

Operations Research and Economics Division

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PREFACE

Services performed under this contract were for the Technical Services Directorate of the Office of Civil Defense.

The RTI Project Leader was Dr. Fred A. Bryan, Jr.; the Group Leader was Mr. Edward L. Hill. Other major contributions were as follows: Mr. Russell O. Lyday performed all modifications to the PF-COMP computer program, made the initial production runs of the program, and was assisted by Mr. Bu[illegible] W. Howard in the formulation and programming of the analytical routine for improving shelters in basement areas on a cost/effectiveness basis; Mr. Philip S. McMullan reviewed the background for OCD use of PF 40 as the minimum acceptable for fallout shelter space; Mr. Milton D. Wright programmed the shelter boundary procedure routine and made the hand computations required for the program test problem.

ABSTRACT

The task assignments in this project were principally concerned with the implementation of a CDC 3600 computer program for computing PF's of structures (PF-COMP) as well as with additions to the program which would make it more useful to architects and engineers. The program was implemented by The Research Triangle Institute (RTI) through the Office of Civil Defense first in the performance of the Military Overseas Shelter Survey (MOSS) and subsequently in the analysis of federal buildings designated by the Office of Civil Defense. Finally, implementation of the computer program as a service to qualified fallout shelter analysts was performed in the Shelter Analysis for New Designs (SAND) program. A principal addition to the PF-COMP computer program which will render it more useful to architects and engineers consisted of an analytical routine for cost effectiveness modification of structures to improve basement shelter PF. Incorporated as a subroutine in this supplementary program is a technique which permits definition of shelter boundary as a function only of percentage roof contribution and shelter location within a structure.

TABLE OF CONTENTS

Protection Analysis and Construction Evaluation System

I. INTRODUCTION

This constitutes the final report of activities completed under Contract No. OCD-PS-65-47. The objective of this contract was to provide technical services to architects and engineers (AE's) through the OCD Architectural and Engineering Services Division. The primary task was the completion of the development of the CDC 3600 computer program (PF-COMP) initiated under Contract No. OCD-PS-64-65. This computer program was designed to perform PF analysis of structures already built as well as those in the planning stage. The contract called for the preparation of the necessary procedures, input forms and output formats to provide qualified fallout shelter analysts with the services of PF-COMP; and for a field test of the procedures, forms, and formats throughout OCD Region 3 initially and finally throughout the nation. A second task of the contract was to formulate and program an analytical procedure for evaluating proposed basement designs and for recommending measures for improving the design on a cost effectiveness basis. The tasks enumerated above have been completed and documented in various research memoranda and special instruction booklets. The contract language is contained in Appendix A.

II. COMPLETION AND DOCUMENTATION OF PF-COMP

The PF-COMP computer program, which was designed to calculate the protection factors in structures, was programmed for the CDC 3600 Computer. The completion of this computer program (initiated under OCD Contract No. OCD-PS-64-65) made possible the calculation of shelter PF's by a digital computer using the Engineering Manual (PM-100-1) techniques.[1/] These techniques are the most accurate available at the present time for the determination of shelter protection factors. The program was documented in Research Memorandum RM-205-1.[2/] Minor revisions and

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[1/] Office of Civil Defense. Design and Review of Structures for Protection from Fallout Gamma Radiation, 1965.

[2/] Hill, et al. Computer Program for Analysis of Building Protection Factors, RTI, 1965.

short-run improvements to the program subsequent to the initial documentation are included in Research Memorandum RM-205-1, Revision 1.[3/]

III. IMPLEMENTATION OF PF-COMP

A. Military Overseas Shelter Survey

The Office of Civil Defense was requested to assist the Department of the Army in determining the available fallout shelter spaces in overseas military installations.

This on-going operation, known as the Military Overseas Shelter Survey (MOSS), served as the first implementation of the PF-COMP computer program. RTI, in cooperation with the Office of Civil Defense, devised the data collection form instructions[4/] and the data collection form[5/] for the survey. Analysts were trained in the use of these materials in courses conducted by OCD in Germany, Okinawa, and Korea. Data collected in this survey are sent to the Bureau of Census where they are collated and put on data tapes. These data tapes are then sent to the National Civil Defense Computer Center (NCDCF) to be analyzed by the PF-COMP computer program on the CDC 3600 machine. RTI performed the initial production runs in this program and subsequently trained NCDCF personnel in program operation. To date, approximately 1,000 structures have been analyzed in the MOSS program by PF-COMP.

B. Federal Buildings

At the request of OCD, analysis of protection offered by several federal buildings was undertaken both independently and in conjunction with AE firms. The first of these analyses was performed on the St. Paul-Minneapolis Court House and Federal Office Building. Subsequently, analyses were performed on the Bureau of Reclamation Building, Denver, Colorado; and on federal office buildings in New York, New York; Jacksonville, Florida; Opelousas, Louisiana; Des Moines, Iowa; and Newark, New Jersey. The buildings in Jacksonville, Opelousas, Des Moines, and Newark were analyzed with the assistance of Thomas B. Bourne, Associates, Inc. of Washington, D. C.

[3/] Hill, et al. Computer Program for Analysis of Building Protection Factors, Revision 1, RTI, 1966.

[4/] Office of Civil Defense. Military Overseas Shelter Survey Data Collection Form Instructions - Phase 1, 1965.

[5/] Office of Civil Defense. Military Overseas Shelter Survey Phase 1 Data Collection Form, 1965.

C. Shelter Analysis for New Designs Program

The third phase of the implementation of the PF-COMP computer program was performed as a service to architects and engineers under the Shelter Analysis for New Designs (SAND) program. Under this program the instructions and data collection forms initially designed for the MOSS program were modified to make them suitable for domestic application. Sixteen firms employing qualified fallout shelter analysts, as indicated in the OCD Directory of Fallout Shelter Analysts[6], were selected at random from OCD Region 3. Each of these firms was invited to assist in the initial field test of the PF-COMP computer program. Replies were received from nine of the sixteen firms. Of these nine, six agreed to submit data for the field test (three indicated that they had no structures in the design phase at the time that would be applicable to the test). During the test period (approximately 2 months), data were received from four of the sixteen firms. A listing of the firms contacted and an indication of their participation is given in Appendix B. The data submitted by these AE firms were processed on the CDC 3600 by the PF-COMP computer program. The results of this computation were returned to the AE firms. Subsequently, these firms were contacted to receive their comments on the clarity and utility of the instructions, data collection forms (DCF's), and computer results. The majority of the comments from this field test indicated that the forms and instructions as first drafted were clear and that the computer results were very useful to the firms submitting data.

Minor modifications were made in the documentation as a result of the Region 3 field test. The new instructions, entitled Shelter Analysis for New Designs, Data Collection Form Instructions[7], and the accompanying DCF's[8] were prepared for the nationwide field test. In the nationwide test, 10 firms in each OCD region were drawn at random from the OCD Directory of Fallout Shelter Analysts. Of the 80 randomly selected firms 15 agreed to submit data for the nationwide PF-COMP field test. A listing of the firms contacted and the extent of their participation is given in Appendix C.

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[6] Office of Civil Defense. National Directory of Architectual, Engineering and Consulting Firms with Certified Fallout Shelter Analysts, 1965.

[7] Office of Civil Defense. Shelter Analysis for New Designs, Data Collection Form Instructions, 1965.

[8] Office of Civil Defense. Shelter Analysis for New Designs Data Collection Form, 1965.

During the nationwide field test period (approximately 2 months), data from two of these firms have been received and processed to date. The results of the computations were returned to the firms submitting data and comments elicited from them as to the utility and clarity of the procedures format and techniques. These comments are to be utilized in final modification of the DCF instructions and data collection forms.

IV. ADDITIONS TO PF-COMP

A. Basement Modification Program

An analytical procedure was developed to evaluate proposed structural designs of basements and to recommend measures for improving the shelter available on a cost effectiveness basis. This basement modification program, discussed in Research Memorandum RM-205-5[9/], considers increments in first floor mass thickness and basement wall mass thickness, and decrements in percent apertures in the basement walls and basement wall exposure. In the procedure, wall mass thickness and wall exposure are varied independently, as one generally precludes the other. However, the percent apertures and overhead mass thickness are considered in combination with each of the above.

The basement modification program which runs in conjunction with the basic PF-COMP program, requires the AE to provide certain basic input data. The AE must specify the minimum percent apertures he will allow, the maximum first floor mass thickness, the maximum exterior wall thickness, and the minimum basement exposure. Apertures and wall thickness are specified on a per side basis; expoaure is specified per sector. Also, the AE is required to specify the cost of these modifications, including increased costs in ventilation and lighting due to decreasing apertures. The program calculates the optimum (least cost) means of achieving a specified number of shelter spaces at a specified protection factor, which the AE also provides as input data.

The output of this basement modification program yields the optimum combination of overhead mass thickness, wall exposure, and percent apertures; or overhead mass thickness, wall mass thickness, and percent apertures. In addition, it yields four alternate optimum designs, each subject to a single restriction.

9/ Howard, et al. Analytical Routine for Cost Effectiveness Modification of Structures to Improve Basement Shelter PF. RTI, 1966.

These are: (1) the optimum configuration with the initial design apertures; (2) the optimum configuration with the initial design first floor mass thickness; (3) the optimum configuration with the initial design wall mass thickness; and (4) the optimum configuration with the initial design wall exposure.

As a subroutine, the basement modification program employs a new shelter boundary procedure devised in this project. The shelter boundary procedure yields the spaces available after modifications are made; this procedure is outlined below.

B. Shelter Boundary Procedure

The shelter boundary procedure developed in this project is a simplified technique for determining the area in a shelter which meets specified protection criteria. This procedure, described in Research Memorandum RM-205-3[10] and Research Memorandum RM-205-4[11], uses the AE Guide[12] techniques to determine ground contribution and the Engineering Manual to find the roof contribution. The results of these determinations were compared with experimental data where possible and were also compared with the Engineering Manual type calculations as performed by the PF-COMP computer program. These comparisons indicate that the results achieved by this simplified shelter boundary procedure are in many cases as accurate as those found by extrapolation or interpolation of results of Engineering Manual calculations at multiple points to determine shelter area. (There is some question of how to handle contributions from setbacks with the shelter boundary procedure due to the manner in which the roof contribution is handled.)

The shelter boundary procedure determines the shelter area having a PF above a specified value. This is done by finding the total reduction factor at the center of the proposed shelter area (or at some other detector location) and then utilizing previously tabulated results to estimate the fraction of the distance toward each wall of the shelter that one could proceed assuming uniform ground contribution. Once this preliminary distance is determined, a correction factor is applied based upon a ratio of the calculated contribution from a particular sector to the average

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[10] Bryan, et al. Fallout Shelter Boundaries. RTI, 1965.

[11] Bryan, et al. Development of Fallout Shelter Boundary Procedures. RTI, 1965.

[12] Office of Civil Defense. Fallout Shelter Surveys; Guide for Architects and Engineers. 1961.

contribution. This technique has been published for use in manual calculations by architects and engineers. It has also been incorporated in the basement modification program for estimating shelter area.

V. SPECIAL TOPICS

A. Review of Protection Factor Criteria for Fallout Shelters

At the request of the Director of the Architectural and Engineering Services Division, a review was made of the background and principal planning which led to the recommendation of PF 40 as the minimum acceptable PF for fallout shelter spaces. This review was published in Research Memorandum RM-205-2[13]. The review of PF criteria reinforced earlier expectations that the recommended protection factor criterion was selected as much by informed judgment as by observations or mathematical analyses. The conclusion reached was that PF 40 provides a 90 percent probability of surviving fallout. This is based on a requirement that the dose be held at or below 200r for survival. Since fatalities occur with less than 100 percent probability for doses between 200r and 600r-700r, it was also observed that the 90 percent survival level is a conservative estimate.

B. Comparison of PF-COMP Results with Engineering Manual Hand Calculations

The PF-COMP computer program was completed in segments with computations by each segment of the program compared with hand computations. Various test buildings were used to verify the accuracy of the total program. Initial simplified test buildings were supplied by Commander J. C. Ledoux who also performed most of the hand calculations for these buildings. The results of this initial comparison are reported in Research Memorandum RM-205-1, Part I. The comparison indicated that the PF-COMP program agrees very well (to a maximum difference of 4%) with the hand calculations.

In addition to the above calculations, hand calculations were also performed using Engineering Manual techniques on 32 NFSS structures in a previous RTI project for the Office of Civil Defense.[14] Comparison calculations were made with PF-COMP for several of these structures. These calculations indicates that the PF-COMP is in good agreement with manual calculations for determining the PF of actual buildings.

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[13] McMullan. A Review of Protection Factor Criteria for Fallout Shelters. RTI, 1965.

[14] Hill, et al. Analysis of Survey Data. RTI, 1964.

C. PF-COMP Test Building

In order to insure the continued accurate operation of a production program, it is always necessary to include a test problem with the program. Such a test problem has been devised for the PF-COMP computer program. This test problem is described in Research Memorandum RM-205-6[15/]. It is based on a seven story building with three setbacks and a partial basement in a rather complex environment of shielding buildings and contaminated planes. The problem incorporates as many of the special types of calculations that one finds necessary in actual structures as could be devised. Engineering Manual calculations were performed by hand for detectors located in the centers of the partial basement, the fifth story, and the sixth story. In addition, calculations were performed for off-center detector locations in the partial basement and on the fifth story. The description of this problem shows the details of the PF-COMP procedure as well as those of the corresponding Engineering Manual hand calculations. The results, given in RM-205-6, show agreement between machine and hand computations with a maximum difference of one PF unit at any of the detector locations. This difference is caused by the precision with which the graphical and/or tabular look-ups can be performed.

This test problem achieves two results. First, it provides a detailed analysis of the accuracy of each element of the PF-COMP computer program as based on Engineering Manual techniques; and second, it provides a basis for continued evaluation of proper operation of the computer program.

The PF-COMP computer program has been supplied to NCDCF personnel for production running. The test building problem, together with input and output description, has also been supplied as an adjunct to this program. In any implementation of the PF-COMP computer program, the test building should always be supplied as an integral part of the program listing and information package. This will insure continued accurate operation of the computer program.

15/ Wright and Lyday. PF-COMP Computer Program Test Building. RTI, 1966.

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Appendix A

Research Triangle Institute Contract No. OCD-PS-65-47
Scope of Work

Appendix A

Research Triangle Institute Contract No. OCD-PS-65-47
Scope of Work

A. The Contractor, in consultation and cooperation with the Government, shall furnish the necessary personnel, facilities, and other services as may be required to complete the development of the CDC 3600 Computer Program (initiated under Contract No. OCD-PS-64-65) to perform PF Analysis for structures under design and evaluate appropriate measures and cost estimated to increase the protection from fallout gamma radiation and provide this service to qualified design architects and engineers. The work and services shall be performed as specifically provided in this contract and generally consistent with the Contractor's proposal dated November 5, 1964.

B. Specific work and services shall include, but not be limited to the following:

1. Implement the present PF computer program (or short-run significant improvements thereto) as a service to qualified design architects and engineers eligible for listing in "Qualified Fallout Shelter Analysts."

2. Formulate and program a series of more refined analytical procedures for evaluating proposed structure designs and recommend measures and costs for improving the design. Emphasis is to be placed upon immediate implemencation of the existing OCD-RTI program, but with a parallel concurrent effort to be undertaken to formulate the computer program modifications so as to facilitate structural analysis.

C. In implementing the program, the contractor shall:

1. Prepare the necessary procedures, input forms, and output formats to provide "qualified fallout shelter analysts" with the services of the RTI program for computing PF's.

2. Field test the above procedures and forms in the RTI area, through OCD Region III, with the assistance of qualified fallout shelter analysts and the North Carolina Civil Defense Office.

3. Determine appropriate procedures for providing PF computational services to qualified fallout shelter analysts through OCD Regional Offices.

4. Revise the procedures as indicated by the field test and prepare instructions for limited distribution, through OCD Regional Offices, to selected qualified fallout shelter analysts throughout the country.

5. Participate with OCD in a nationwide test of the procedure by:

a. Assisting OCD and Regional Offices in the selection of structural designs for evaluation.

b. Monitor the collection and processing of data, computation of PF's, and return of results to the OCD Regional Office.

c. Prepare evaluations of PF results and submit evaluations to the qualified fallout shelter analysts through the appropriate OCD Regional Office.

d. Follow-up with OCD Regions and qualified fallout shelter analysts to determine adequacy of the program and procedures. Revise the program and the instructions as indicated by the results of the follow-up.

e. Train OCD personnel in Washington, as necessary, to permit continuous use of the program as a service to qualified fallout shelter analysts.

f. Provide consultation, as requested, to OCD personnel in Washington or in the field on use of the PF program and analysis of output.

D. The formulation of an analytical routine to determine measures and costs to improve shielding and/or shelter capacity of new construction designs will progress in parallel with PF program implementation. Structures submitted in the test of the implementation procedures will be employed in evaluating analytical procedures. The evaluation will concentrate first on providing recommended changes in shielding characteristics. This will be followed by an examination of the costs associated with those improvements and the incorporation of cost analysis in the analytical procedure. The proposed formulation will be submitted to OCD and, upon approval, programmed for the CDC 3600. Output for this program will then be incorporated in the services offered to qualified fallout shelter analysts.

Appendix B

Random Sample of OCD Region 3 AE Firms

This appendix contains a list of architectural, engineering, and consulting firms contacted during the OCD Region 3 field test of PF-COMP. Each of these firms was invited to assist in the field test; the extent of their participation is noted in the listing.

Appendix B

Random Sample of OCD Region 3 AE Firms[1/]

Alabama (11)[2/]

Jamison Engineering
Civil Engs. & Land Surveyors
403 20th Avenue
P. O. Box 506
Tuscaloosa, Ala.

Reed-Mullins & Asso.
Architects & Engineers
A Division of Brown Eng. Co.
P. O. Box 1287, W. Station
Huntsville, Ala. ✓(IN)

The Rust Engineering Co.
Engineers-Constructors
2316 Fourth Ave. North
Birmingham 3, Ala. ✓(IN)

Florida (58)

Dignum Associates
Consulting Engineers
260 Palermo Avenue
Coral Gables
Miami 34, Fla. ✓(NO)

Raymond S. Dunphy
Structural Engineers
245 Lombardy Ave.
Lauderdale-by-the-Sea, Fla.

Fiske-Gay Associates, Inc.
Consulting Engineers
4720 N. Orange Blossom Trail
Box 7774
Orlando, Fla.
Branch Office: P. O. Box 513
Lakeland, Fla.

Florida (58)

W. R. Gomon & Asso.
Architects
P. O. Box 1671
Municipal Airport
Daytona Beach, Fla., 32015✓

Reynolds, Smith & Hills
Architects & Engineers
P. O. Box 4850
Jacksonville 1, Fla.
Branch Office: Box 1015, Tampa
Box 8006, Orlando, Fla✓(IN)

R. James Robbings, AIA
Architect
608 Exchange National Bank Bldg.
605 Franklin St.
Tampa, Fla., 33602 ✓(IN)

Georgia (18)

Boroughs and Baldwin
Architects and Engineers
465 E. Paces Ferry Rd., N.E.
Atlanta, Ga., 30305

James C. Wise, Simpson,
Aiken & Associates
Architects & Engineers
873 Spring St., N.W.
Atlanta, Ga., 30308

South Carolina (9)

(None Selected)

Mississippi (9)

Brewer, Skewes & Godbold
Architects & Engs.
P. O. Box 487
Clarksdale, Miss.
✓(NO)

North Carolina (12)

Charles T. Main, Inc.
Consulting Engineers
129 W. Trade St.
Charlotte 2, N. C.

Tennessee (13)

Stuart R. Daniels
Consulting Engineer
824 W. Hills Rd.
Knoxville, Tenn.✓

Lindsay & Maples
Architects
1301 Hannah Ave.
Knoxville, Tenn.

Mason & Hanger-Silas
Mason Co., Inc.
Engineers & Contractors
Clarksville Base
Clarksville, Tenn.
42222 ✓(NO)

1/ Drawn from 'National directory of Architectural, Engineering and Consulting Firms with certified Fallout Shelter Analysts.

2/ The number in parenthesis is the number of AE firms in this particular state employing Certified Fallout Shelter Analysts. The sample was drawn from the entire region, not apportioned by states.

NOTE: A ✓ indicates a reply to enlistment letter for field test participation;
(NO) indicates the firm had no building applicable to the field test;
(IN) indicates data processed on a building submission.

Appendix C

Random National Sample of AE Firms

This appendix contains a list of architectural, engineering, and consulting firms contacted during the OCD nationwide field test of PF-COMP. Each of these firms was invited to assist in the field test; the extent of their participation is noted in the listing.

Appendix C

Random National Sample of AE Firms[1/]
(10 firms drawn from each OCD region)

REGION ONE

Connecticut (21)[2/]

A. J. Marchi, Engineers
Associate Consultant
44 Gillett St.
Hartford, Conn.

Charles A. Maguire & Asso.
Engineers
530 Silas Deane Highway
Wethersfield, Conn., 06109 ✓

Maine (7)

(None Selected)

Massachusetts (41)

Newmark, Hansen & Asso.
Consulting Engineers
P. O. Box 431
Cambridge 39, Mass.

New Hampshire (2)

(None Selected)

New Jersey (49)

Louis Berger & Asso.
Consulting Engineers
177 Oakwood Ave.
Orange, N. J.

John M. O'Donovan
Consulting Engineer
161 West Grand Ave.
Montvale, N. J., 07645

New Jersey (49)

Vogelbach & Baumann
Consulting Engineers
2507 Route 22
Scotch Plains, N. J., 07076 ✓

New York (149)

Erdman & Anthony
Consulting Engineers
Case Building
82 St. Paul St.
Rochester, N. Y., 14604

MacKnoght, Kirmmse & French
Architect and Engineers
6443 Ridings Rd.
Syracuse, N. Y., 13206

Mayer Associates
Consulting Engineers
110 East 30th St.
New York, N. Y., 10016

Puerto Rico (19)

Lockwood, Kessler & Bartlett, Inc.
Consulting Engineers
San Juan, P. R.

Rhode Island (4)

(None Selected)

Vermont (5)

(None Selected)

REGION TWO

Delaware (4)

(None Selected)

District of Columbia (42)

(None Slected)

Kentucky (29)

Mason & Hanger-Silas
Mason Co., Inc.
Engineers and Contractors
218 E. Main St.
Lexington, Ky., 40507

Maryland (31)

George, Miles & Buhr
Architects and Eng.
Salisbury, Md.

Ohio (77)

Elgar Brown
Consulting Engineer
4355 N. High St.
Columbus, Ohio, 43214

Engineering Asso.
700 Winkler Dr.
P. O. Box 157
Wooster, Ohio, 44692

1/ Drawn from "national directory of Architectural. Engineering and Consulting Firms with Certified Fallout Shelter Analysts."

2/ The number in parenthesis is the number of AE firms in this particular state employing Certified Fallout Shelter Analysts. The sample was drawn from an entire region, not apportioned by states.

NOTE: A ✓ indicates a reply to enlistment letter for field test participation;
(NO) indicates the firm had no building applicable to the field test;
(IN) indicates data processed on a building submission.

Random National Sample of AE Firms (Continued)

REGION THREE

Ohio (77)

Green-Smith-Francis
Architecture and Engineering
71 E. Washington St.
Painesville, Ohio
Branch Offices: Ashtabula and Willoughby , Ohio

Lay, Koski & Asso.
Architects and Engineers
665 W. Market St.
Akron, Ohio, 44303

John M. Stoudt
Consulting Engineer and Chemist
104 William Howard Taft Rd.
Cincinnati, Ohio, 45219

Symms, Carlson, Englehorn & Associates
Architect-Engineers
2930 Prospect Ave.
Cleveland, Ohio, 44115

Pennsylvania (84)

(None Selected)

Virginia (32)

Pope, Evans & Robbins
Consulting Engineers
515 Wythe St.
Alexandria, Va.

West Virginia (10)

Alden E. Stilson & Asso.
Consulting Engineers Limited
Wheeling, W. Va.

Alabama (11)

Robert H. Wallace
Consulting Engineers
308 Title Bldg.
Birmingham 3, Ala.

Florida (58)

Brockway, Weber & Brockway Engineers
Guaranty Bldg.
West Palm Beach, Fla.
Branch Office: Palm Beach Gardens, Fla.

Crain Engineering Co.
3061 N. W. 7th St.
Miami, Fla., 33125

Evans & Hammond, Inc.
Consulting Engineers
2756 Park St.
Jacksonville, Fla., 32205

Interstate Engineering Co.
Consulting Engineers
1100 N.E. 125th St.
North Miami, Fla., 33161

D. F. Ludovici
Consulting Engineers
1112 Dupont Plaza Center
Miami, Fla.

Michaels Engineering Co.
Consulting Engineers
Michaels Bldg.
3025 E. South St.
Orlando, Fla., 32803

Florida (58)

Smally, Wellford & Nalven
Consulting Engineers
133 S. McIntosh Rd.
Sarasota, Fla., 33578 ✓ (NO)

Georgia

William H. Breen, Jr.
Architect
105 E. Court Square
Decatur, Ga.

William F. Burton
Professional Engineer
1584 Timberland Rd. N.E.
Atlanta, Ga., 30329

Mississippi (9)

(None Selected)

North Carolina (12)

(None Selected)

Tennessee (13)

(None Selected)

Random National Sample of AE Firms (Continued)

REGION FOUR

Illinois (59)

Consoer, Townsend & Asso.
Consulting Engineers
360 E. Grand Ave.
Chicago, Ill., 60611

Ebasco Services, Inc.
Engineers, Constructors, and
Business Consultants
135 South LaSalle St.
Chicago 3, Ill.

Knoerle, Bender, Stone &
Asso., Inc.
Consulting Engineers
211 W. Wacker Dr.
Chicago, Ill., 60606

Zion Engineering &
Construction Co.
Box 2
Zion, Ill.
Branch Office: 1287 Brown St.
Des Plaines, Ill.

Indiana (15)

Architects and Engineers
1718 W. Fifteenth St.
Indianpolis, Ind. ✓

Michigan (30)

John G. Hoad & Asso., Inc.
Consulting Engineers
8 E. Michigan Ave.
Ypsilanti, Mich. ✓

A. Charles Jones Asso., Inc.
G-3050 W. Pasadena Ave.
Flint, Mich.

Minnesota (22)

Land, Raugland & Brunet, Inc.
Architects-Engineers
802 Wesley Temple Bldg.
Minneapolis 3, Minn. ✓

Wisconsin (25)

General Engineering Co.
Consulting Engineers
317 DeWitt St.
P. O. Box 71
Portage, Wis.

Hartman-Strass, Inc.
Eonsulting Engineers
2344 N. Oakland Ave.
Milwaukee, Wis., 53211
Branch Office: 821 N. 14th St.
Sheboygan, Wis., 53802 ✓

REGION FIVE

Arkansas (10)

(None Selected)

Louisiana (37)

August Perez & Asso.
Architects
2609 Canal St.
New Orleans, La.

New Mexico (11)

Flatow, Moore, Bryan &
Fairburn
Architects and Engineers
5301 Central NE., Suite 1600
Albuquerque, N. Mex., 87108
✓(NO)

Oklahoma (27)

Howard, Samis, Davies &
Van Doren
Engineers and Architects
703 Hightower Bldg.
Oklahoma City, Okla.,
73102 ✓(NO)

Rea Engineering & Asso.
Consulting Engineers
1301 SW. 74th
P. O. Box 19187
Oklahoma City, Okla.,
73119

Texas (86)

Sam Biderman, Jr.
Consulting Engineer
1220 Dallas Athletic
Club Bldg.
Dallas 1, Tex.

Dale S. Cooper & Asso.
Consulting Engineers
3815 Garrott St.
Houston, Tex., 77006 ✓

J. B. Dannenbaum
Consulting Engineer
3915 Essex
Houston 27, Tex.

Pitts, Mebane, Phelps &
White
Architects and Engineers
1872 Calder Ave.
Beaumont, Tex., 77701

William R. Pounders, Jr.
Architect
603 W. Huisache at North
Flores
San Antonio, Tex., 78212

Random National Sample of AE Firms (Continued)

Texas (86)

Reagan & McCaughan
Consulting Engineers
320 Wilson Bldg.
Corpus Christi, Tex., 78401 ✓

REGION SIX

Colorado (21)

AA Engineers & Asso.
Consulting Engineers
1737 Central St.
Denver, Colo., 80211

Colorado-Ute Electric Association, Inc.
Box 178
Montrose, Colo., 81401

Iowa (18)

F. W. Mann & Asso.
Civil Engineering
1016 Military Ave.
Council Bluffs, Iowa, 51501 ✓ (NO)

Kansas (21)

Glenn E. Benedick
Architect
230 Laura
Wichita, Kans., 67211 ✓ (NO)

Hollis & Miller
Architects and Engineers
9417 W. 75th St.
Overland Park 4, Kans.

Missouri (45)

Black & Veatch
Consulting Engineers
1500 Meadow Lake Pkwy.
Kansas City, Mo., 64114 ✓

Missouri (34)

Burgwin & Martin
Consulting Engineers
Suite 203
3718 Broadway
Kansas City, Mo., 64111

Nebraska (11)

B. H. Backlund & Asso., Inc.
Engineers, Architects, and Planners
3555 Farnam St.
Omaha, Nebr., 68131

Kirkham, Michael & Asso.
Engineers & Architects
Omaha, Nebr.

North Dakota (10)

(None Selected)

South Dakota (8)

(None Selected)

Wyoming (7)

(None Selected)

REGION SEVEN

Arizona (21)

Beck, Edson & Golblatt
Architects
3134 E. 2nd. St.
Tucson, Ariz. ✓ (NO)

California (137)

Allied Engineering
Designers-Engineers-Fabricators-Erectors
11810 Center St.
South Gate, Calif.

Consoer, Townsend & Asso.
Consulting Engineers
132 Race St.
San Jose 26, Calif.

Charley C. Curtis
Consulting Engineer
3667 Atlantic Ave.
Long Beach, Calif., 90807

Garretson-Elmendorf-Klein-Reibin
Architects-Engineers
124 Spear St.
San Francisco, Calif., 94105

Raymond M. Knowles & Asso.
Architects-Engineers-Planners
4460 Park Blvd.
San Diego, Calif., 92116

Arthur A. Sauer & Asso.
Engineers
2203 13th St.
Sacremento, Calif., 95818 ✓

Schlintz & Ostrander Asso. Engineers, Inc.
Consulting Engineers
3725 E. Belmont Ave.
Fresno, Calif., 93720

South Bay Engineering Corp.
P. O. Box 818
43 Malaga Cove Plaza
Palos Verdes Estates, Calif. ✓

Random National Sample of AE Firms (Continued)

Hawaii (5)

(None Selected)

Nevada (5)

(None Selected)

Utah (11)

Rader and Asso.
Engineers and Architects
445 E. 2nd. St.
Salt Lake City 11, Utah

REGION EIGHT

Alaska (3)

(None Selected)

Idaho (10)

(None Selected)

Montana (12)

Associated Engineers-
Architects
Professional Bldg.
P. O. Box 201
Butte, Mont.

Bordeleau-Amundson &
Hauck
Architects
309 First Ave., N.
P. O. Box 1163
Great Falls, Mont.

J. G. Link & Co.
P. O. Box 1313
Billings, Mont.
Branch Office: 2303 Ottawa
Butte, Mont. ✓

Montana (12)

Orr Pickering & Asso.
Architects and Engineers
310 Fratt Bldg.
Billings, Mont., 59101 ✓ (IN)

Oregon (14)

Stuart B. Mockford, Arch.
723 Washington St.
Oregon City, Oreg.

Washington (43)

Hill & Ingman
Consulting Engineers
3104 Western Ave.
Seattle, Wash., 98121

McClure & Adkison, Arch.
707 Sherwood Bldg.
Spokane, Wash., 99201 ✓

E. Norman Sylvester
Architect
327 Old National Bank Bldg.
Spokane, Wash., 99201

Tippetts-Abbett-McCarthy-
Stratton
Engineers and Architects
1325 Fourth Ave.
Seattle 1, Wash.

Thomas O. Williams & Asso.
Architects
20 S.E. Third
College Place, Wash.

Firms Contacted During the Nationwide Field Test in Addition to the Random National Sample

S. Cafarelli Associates
Consulting Engineers
11 East 44th Street
New York, N. Y. √ (IN)

Guirey, Srnka & Arnold
Architects
Suite 303
3800 N. Central
Phoenix 12, Arizona √ (NO)

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13 ABSTRACT The task assignments in this project were principally concerned with the implementation of a CDC-3600 computer program for computing PF's of structures (PF-COMP) as well as with additions to the program which would make it more useful to architects and engineers. The program was implemented by The Research Triangle Institute (RTI) through the Office of Civil Defense first in the performance of the Military Overseas Shelter Survey (MOSS) and subsequently in the analysis of federal buildings designated by the Office of Civil Defense. Finally, implementation of the computer program as a service to qualified fallout shelter analysts was performed in the Shelter Analysis for New Designs (SAND) program. A principal addition to the PF-COMP computer program which will render it more usefui to architects and engineers consisted of an analytical routine for cost effectiveness modification of structures to improve basement shelter PF. Incorporated as a subroutine in this supplementary program is a technique which permits definition of shelter boundary as a function only of percentage roof contribution and shelter location within a structure.

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14 KEY WORDS	LINK A		LINK B		LINK C	
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Fallout Shelters						
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Surveying						
Shielding						
Programming						
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